APPENDIX C-1

SUPPLEMENTAL HYDROGEOLOGIC INVESTIGATION REPORT

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GREGORY CANYON LANDFILL
SAN DIEGO, CALIFORNIA

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PREPARED FOR:

Gregory Canyon, Ltd.
3 Embarcadero Center, Suite 2360
San Francisco, California 94111

PREPARED BY:

GeoLogic Associates
16885 West Bernardo Drive, Suite 305
San Diego, California 92127

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GREGORY CANYON LANDFILL
SAN DIEGO COUNTY

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1.0 INTRODUCTION

This report documents the installation and testing of additional groundwater monitoring wells at the proposed Gregory Canyon Landfill (GCLF) site located in northern San Diego County, California (Figure 1). GeoLogic Associates (GLA) completed the work on behalf of Gregory Canyon Limited in response to comments from the Regional Water Quality Control Board – San Diego Region (RWQCB) on the Joint Technical Document (JTD) for discharge of municipal solid waste at the proposed GCLF site submitted on April 9, 2004. In a letter dated May 28, 2004, the RWQCB noted that the following components were missing from the JTD.

1. Documentation for installation of additional groundwater monitoring wells.
2. Results of aquifer pump tests of the proposed groundwater monitoring network.
3. An acceptable demonstration that the proposed monitoring network will be able to provide the earliest detection of a release of waste constituents to groundwater from the proposed solid waste management unit at Gregory Canyon.

Project work was performed to supplement the Geologic, Hydrogeologic, and Geotechnical Investigations Report (GLA, May 2003), and to address the concerns listed above by the RWQCB. Site background information is provided in the GLA (May, 2003) report.

Well installation and testing project was completed between June and August 2004 under the supervision of a geologist registered in the State of California, and in general accordance with the well installation specifications developed by GLA for the Gregory Canyon Landfill project. The project's scope of work involved the following activities:

- Drilling and geologic logging of 11 exploratory borings using hollow-stem auger and air rotary casing hammer (ARCH) techniques;
- Logging of each bedrock boring using borehole geophysics;
- Installation of nine groundwater monitoring wells;
- Well modifications to grout up the lower portions of two open hole wells;
- Conducting aquifer testing including variable-rate, constant-rate, and slug tests;
- Evaluation of the site groundwater environment and proposed groundwater monitoring network primarily along the point of compliance;
- Preparation of this report.

Each of the field activities are described in Section 2.0 below followed by presentation of our interpretation of the field data in Section 3.0, a discussion and interpretation of the data relative to the site itself in Section 4.0 and a summary of conclusions developed from this hydrogeologic investigation in Section 5.0.

2.0 SITE ACTIVITIES

Based on discussions with RWQCB staff, GLA selected 11 locations for exploratory drilling and subsequently constructed groundwater monitoring wells in nine of these borings (Figure 2). In addition, at the request of the RWQCB, two existing wells (GLA-2 and GLA-10) were modified to include grouting up the lower portion of their open hole construction. A summary of the drilling and well construction program is summarized on Table 1. GLA supervised the drilling and monitoring well installation work from June 3 through July 22, 2004, and aquifer pumping tests were subsequently completed through August 30, 2004. Prior to mobilization, permits for well drilling and construction were obtained from the County of San Diego Department of Environmental Health. GLA met with the URS Corporation (project biologist) at Gregory Canyon on May 24, 2004 to also review the proposed drilling locations for potential biological concerns. All excavations (access roads, drill pads, and borings) were subsequently monitored by SWCA Environmental Consultants (project archeologists) for archeological artifacts that might be exposed during excavation or drilling.

2.1 DRILLING PROGRAM

Alluvial borings (Lucio-2R and SLRMWD #34R) were drilled using a CME-95 hollow-stem auger (HSA) drilling rig to excavate 8-inch nominal diameter borings. The remaining nine bedrock borings were drilled using a Speed Star-30K ARCH drilling rig to excavate 8.5-inch-diameter borings. All drilling was performed by Water Development Corporation (WDC), a California-licensed well drilling company. During drilling, grab samples were collected at regular intervals from the drill cuttings for logging of subsurface conditions. Upon retrieval, the soil samples were logged and the following items were recorded on boring logs:

- Color;
- Soil type or rock type;
- Grain size;
- Rock hardness;
- Presence of potential marker beds;
- Presence of groundwater;
- Degree of weathering or alteration;
- Unified Soil Classification; and
- Other pertinent observations.

The boring logs are provided in Attachment A. During drilling six mil-thick plastic sheeting was used to protect the ground surface near work areas. Upon completion of drilling at each location, the drilling equipment and surplus materials were removed from the site.

After reaching target depth, each bedrock boring was also logged using borehole geophysics. Geophysical logging was completed by COLOG and as described in Section 2.3.

2.1.1 Exploratory Borings

Although proposed groundwater monitoring wells GLA-3S and GLA-17 were drilled to their target depths of 80 and 500 feet below ground surface (bgs), these wells were not completed as groundwater monitoring wells. Proposed groundwater monitoring well GLA-3S was to be screened across both the saturated alluvium and bedrock above the producing zone identified in well GLA-3. However, first groundwater was encountered within the bedrock at a depth of 52 feet bgs, 16 feet below the alluvium/bedrock contact. The static water level was measured at 24 feet bgs, defining the potentiometric surface in the bedrock fracture flow system. Since completing well GLA-3S would only duplicate the groundwater monitoring capability already provided by existing wells GLA-3 and GMW-1, the borehole was abandoned following completion of borehole geophysics. Well GLA-17 was proposed to monitor groundwater along the northwestern ridge of Gregory Canyon (Plate 1), however the borehole was drilled to a total depth of 500 feet bgs and remained dry. Therefore, the borehole was abandoned following completion of borehole geophysics. Previous wells drilled on the western ridge (GMP-3 and GLA-9) were also found to be dry, or recharged only by perched water (e.g., GLA-4), suggesting that the western (tonalite) ridge of Gregory Canyon may act as a groundwater barrier.

2.1.2 Groundwater Well Modifications

At the request of the RWQCB, the bottom of two open borehole wells, GLA-10 and GLA-2, were sealed using a cement/bentonite grout slurry (Plate 2). The grout consisted of a mixture of neat, Type II (Portland) cement and bentonite powder. The bentonite was added at a rate of approximately 5% by dry weight of cement. The grout was thoroughly mixed in small batches using pressure nozzles to circulate the mixture. Water was added at a rate of approximately 10 gallons per sack of cement. The grout seal was placed using tremmie pipe and positive displacement techniques to fill the borehole annulus under pressure to the ground surface. Since well GLA-10 is a designated water level measuring station only, it was sealed to a depth of 57 feet bgs and will remain as an open hole across the bedrock section of the well. Well GLA-2, which will be included as a site groundwater monitoring well, was sealed to a depth of 103 feet bgs, and was subsequently reamed to 8.5-inches to the depth of 104 feet bgs to facilitate construction of a cased well.

2.2 MONITORING WELL CONSTRUCTION

Monitoring wells were designed and constructed in accordance with the project specifications. Well construction summary diagrams showing well construction details along with the boring logs are presented in Attachment A and summarized in Table 1.

As detailed in Attachment A, seven bedrock monitoring wells (and one well [GLA-2] that was modified) were constructed using factory-sealed, flush-threaded, 4-inch diameter schedule 40 PVC, and two alluvial wells were constructed with factory-sealed, flush threaded 2-inch diameter schedule 40 PVC casing. The wells were constructed with 20- to 50-foot-long well screens with 0.020-inch-wide, factory-milled slots. Stainless steel centralizers were placed at the top and bottom of the screen and at 40-foot intervals.

Commercial washed and graded Monterey-type sand filter pack was placed in the annular space between the borehole wall and the well screen. GLA selected #3 sand (in combination with 0.020-inch screen slots) for use as well "filter pack." During installation, the depth to the top of the filter pack was measured periodically to verify the volume of sand in the well annulus. Filter pack sands were placed from the bottom of the boreholes to approximately 2 feet above the top of the well screen. The wells were then pre-developed by surging to settle the filter pack. Following pre-development, additional sand was placed in the annulus, as necessary, to maintain at least 2 feet of separation between the top of screen and the top of the filter pack.

A minimum 4-foot-thick layer of bentonite chips was placed in the annulus above the sand filter pack to isolate the upper grout slurry seal from the well screen section. Medium-sized bentonite chips were placed directly on top of filter pack sands. These materials were wetted (if necessary), and allowed to hydrate for not less than 60 minutes. If the bentonite seal was higher in elevation than the static water level in the well, the bentonite chips were hydrated with approximately 10 gallons of water per foot of chips. Following hydration, the depth to the top of the seal was measured to verify conformance with well design.

Following bentonite seal placement, the remainder of the annular space between the well casing and borehole wall was sealed using a cement/bentonite grout slurry. The grout consisted of a mixture of neat, Type II/V (Portland) cement and bentonite powder. The bentonite was added at a rate of approximately 5% by dry weight of cement. The grout was thoroughly mixed in small batches using pressure nozzles to circulate the mixture. Water was added at a rate of approximately 10 gallons per sack of cement. The grout seal was placed using tremie pipe and positive displacement techniques to fill the borehole annulus under pressure to 3 feet bgs.

Each monitoring well was completed with the addition of concrete from the top of the grout to the surface and a protective surface completion. A 5-foot long, 10-inch-diameter, lockable steel stand pipe with a hinged lid was embedded in a 5-foot by 5-foot square, minimum 4-inch-thick concrete pad and each monitoring well was secured with a padlock. In addition, two 4-inch-diameter, concrete-filled bollards (crash posts) were installed at wells GLA-B and GLA-G. Each bollard was installed to a depth of 2 feet below ground and extended to at least 3 feet above ground.

2.2.1 Well Development

Following construction, the new monitoring wells were developed in general accordance with the project specifications using the procedures described in the following sections. Final well development was completed for each newly installed well on July 6 and 22, 2004. Development activities typically included the following:

- Initial static water level measurement;
- Surging to remove sediment from the filter packs;
- Bailing to remove suspended solids from groundwater in well casings;
- Pumping to remove residual sediments; and
- Final static water level measurement.

Bailing and pumping were performed until waters brought to the surface were generally sediment free and "visually" clear. Pertinent development information is summarized on the monitoring well completion summaries included in Attachment A.

2.2.2 Well Survey

Nolte and Associates, a California Registered Land Surveyor determined the location (northing and easting), pad elevation, top of well monument elevation, and top of PVC well casing elevation for each new monitoring well. Units of measure were U.S. survey feet, and were determined to an accuracy of 0.03 foot (an accuracy deemed adequate for this high relief site). The top of the well monument elevation was measured at the center of the monument. The top of PVC casing elevation was measured from the north side of the casing. Well survey data are summarized on Table 2. Groundwater equipotential contours based on the new wells are presented on Plate 1.

2.3 GEOPHYSICAL LOGGING

Prior to well construction or borehole abandonment, the nine borings that were completed within bedrock were logged using borehole geophysics by COLOG, Inc. between June 11, 2004 and July 21, 2004. Borehole geophysics included the following logs:

- optical televiewer
- neutron log;
- gamma log;
- dual-induction log;
- 4pi-density log;
- water quality log (temperature, electrical conductivity).

These geophysical tools were used for fracture and feature analysis to evaluate fracture orientations and other characteristics such as aperture and mineral infilling, and identification of water producing fractures or zones. The geophysical logs are included in Attachment B and are summarized in Section 3.1.

2.4 AQUIFER TESTING PROGRAM

In response to comments from the RWQCB, GLA conducted an aquifer testing program to evaluate the hydraulic properties of the bedrock fracture flow system in Gregory Canyon and to demonstrate the extent of hydraulic interconnection in Gregory Canyon wells at the point of compliance. The program included long-term variable discharge pumping tests, long-term constant rate discharge pumping tests, and slug tests (drawdown-recovery). Pump test data are included in Attachment C.

For both variable discharge and constant rate pump tests, a Grundfos Redi-Flo 2 electric submersible pump was used (except for the test on well GLA-3 pumping test where a Grundfos 4-inch electric submersible pump was used). The pump was typically positioned between two to three feet above the well bottom. A check valve was plumbed into the discharge pipe approximately one foot above the top of the pump to prevent back-flow of pumped water. An analog totalizer was used to quantify the volume of groundwater discharged during each test, and periodically during each test, the analog flow meter's accuracy was verified using a stop watch and five-gallon bucket. Vented pressure transducers and a digital data logger were used to measure and record the aquifer response to pumping in the test well and the observation well(s). In accordance with RWQCB discharge guidelines and based on the groundwater chemistry determined from historical water quality data from wells on the project site, water generated during the pump tests was discharged to the ground.

2.4.1 Variable Discharge Tests

Long–term variable discharge tests were performed on June 18 and 28, 2004. Figures 3 through 5 depict time-drawdown curves for the pumping wells and observations wells along with time-barometric pressure, and time-pumping rate. Each of these tests are described below, while a discussion of the overall results as they relate to the site characteristics is provided in Section 3.0.

GLA-A Test - The GLA- A variable discharge test was begun at 15:12 on June 14, 2004, and included observation wells GLA-2, GLA-D, and GLA-14 at distances of 191 feet, 315 feet, and 410 feet, respectively, from the pumping well. As shown on the time-pumping rate graph on Figure 3, the test began at an initial pumping rate of 3.0 gallons per minute (gpm), but after 496 minutes, the pumping well dewatered. Although the pumping well was allowed to recover and was restarted the pumping well dewatered again. Following a second recovery, the pump rate was adjusted so the well would not dewater, with pumping rates continued to be reduced to 1.1 gpm (the lowest functional pumping rate). The test ended at 15:16 on June 16, 2004 after about 48 hours (2884 minutes). A total of about 4,222 gallons of water was pumped from well GLA-A, and at the end of the test, drawdown in the pumping well was measured at 17.88 feet. However, there was insufficient groundwater in the fracture flow system to sustain an effective pumping test, and no clear influence from the pumping well was recognized during this test (Figure 3).

GLA-3 Test - The GLA-3 variable discharge test began at 13:04 on June 18, 2004, and included observation wells GLA-C, GLA-B and GLA-12 at distances of 240 feet, 370 feet and 545 feet, respectively, from the pumping well. Wells GMW-1 and GLA-13 were not included as observation wells for this test since they had been included previously in a pumping test conducted in 2000 (GLA, 2001). The test began at an initial pumping rate of 10 gpm using a Grundfos 4-inch electric submersible pump set approximately 50 feet off the bottom of the well. After 296 minutes, the pumping rate was increased to 12 gpm. After 1,135 minutes, the pumping rate was increased to 15 gpm, and after 1,316 minutes the pumping rate was increased to 16.7 gpm for the remainder of the test. The test ended at 7:06 on June 20, 2004 after about 42 hours (2,522 minutes). At the end of the test 35,833 gallons of water had been pumped and the drawdown in the pumping well was measured at 29.43 feet. The observed groundwater response in observation well GLA-C (the closest well to pumping well GLA-3) was erratic (e.g., increasing during much of the test) and a malfunctioning transducer is suspected. As shown on Figure 4, groundwater levels in observation well GLA-B steadily decreased (approximately 0.35 foot) over the duration of the test. However, observations in well GLA-12 initially decreased sharply (to 120 minutes), followed by only slight response and appeared to be mimicking barometric pressure.

GLA-B Test - The GLA-B variable discharge test began at 15:02 on June 28, 2004, and included observation wells GLA-C and GLA-12 at distances of 135 feet and 200 feet, respectively, from the pumping well. It should be noted that at the time of this variable discharge test, well GLA-G (located between wells GLA-B and GLA-12) had not yet been constructed. The test began with an initial pumping rate of 1.8 gpm, but after 148 minutes, the well dewatered. The pumping well was allowed to recover for 30 minutes. Following recovery, the pump rate was lowered so the well would not dewater, with pumping rates varying from 1.3 gpm to 1.65 gpm. The test ended at 15:58 on June 29, 2004 after about 25 hours (1,498 minutes). At the end of the test about 2,179 gallons of water had been pumped and the drawdown in the pumping well was measured at 28.42 feet. As shown on Figure 5, groundwater levels in observation well GLA-C steadily decreased (approximately 0.26 foot) over the duration of the test. However, the groundwater level in well GLA-12 appears to mimic barometric pressure, with no discernable drawdown response to the pumping well.

2.4.2 Constant Rate Tests

Long-term constant rate pumping tests were performed on June 21 and July 28, 2004. Figures 6 and 7 depict time-drawdown curves for the pumping wells and observations wells along with time-barometric pressure, and time-pumping rate.

GLA-13 Test - The GLA-13 test was performed at a relatively constant rate of 4.3 gpm, beginning at 15:02 on June 28, 2004. Two observation wells GLA-D and GLA-2 were selected at distances of 172 feet and 312 feet, respectively, from the pumping well. It should be noted that at the time of this pumping test, well GLA-F had not yet been constructed. In addition, a previous test including GLA-13 and GLA-3 demonstrated communication between these two wells (GLA, 2001), and therefore, GLA-3 was not included as an observation well during this test. The test ran for about 20 hours (1,167 minutes). At the end of the test about 5,018 gallons of water had been pumped and the drawdown in the pumping well was measured at 3.89 feet. As shown on Figure 6, groundwater levels in observation well GLA-D steadily decreased (approximately 0.34 foot) over the duration of the test, while the groundwater level in GLA-2 appears to mimic barometric pressure, with no discernable responses to the pumping well.

GLA-G Test - The GLA-G test was performed at a relatively constant rate of 2.5 gpm, beginning at 15:00 on July 28, 2004. Two observation wells GLA-B and GLA-12 were selected at distances of 101 feet and 101.5 feet, respectively, from the pumping well. The test ran for about 24 hours (1,438 minutes). At the end of the test about 3,603 gallons of water had been pumped and the drawdown in the pumping well was measured at 14.0 feet. As shown on Figure 7, groundwater levels in the observation wells decreased steadily over the duration of the test. The groundwater level in GLA-B steadily decreased approximately 0.84 foot, and in GLA-12 the groundwater level decreased approximately 0.27 foot.

2.4.3 Slug Tests

After reviewing the variable rate and constant rate pump test results, and all drilling logs, it appeared that three fracture flow domains could be identified as follows (Plate 1):

- A groundwater flow barrier formed by the unweathered tonalite underlying the west ridgeline;
- A low flow zone forming an extension of the west ridgeline; and
- A maximum flow zone along the axis of Gregory Canyon in the weathered bedrock zone.

The groundwater barrier was evident in wells GLA-9, GMP-3, GLA-4, and exploratory boring GLA-17 on the upper west ridge of Gregory Canyon. The low flow zone extends north into the "saddle" area near well GLA-2 (Plate 1). As is evident in well GLA-2, groundwater recovery is very slow and aquifer pumping tests do not show a measurable response to pumping at wells GLA-A or GLA-13. Groundwater monitoring wells GLA-E and GLA-F (Plates 1 and 2) were drilled to further investigate this apparent low flow zone/groundwater barrier. While all three wells (GLA-2, GLA-E and GLA-F) have measurable groundwater, none of these wells were amenable to traditional pumping tests due to slow recovery rates. Therefore, in order to evaluate the hydraulic properties within this low flow zone, slug tests were performed instead. At each well, a bailer was used to remove the water from the borehole, and remote data recorders (In-Situ Trolls) were installed in the bottom of each well to measure recovery.

<u>GLA-2 Slug Test</u> - The GLA-2 slug test was performed on August 2, 2004. Prior to bailing, the water level was measured at 73.28 feet bgs. Approximately 25 gallons of water was removed from the well and the water level was measured at 93.86 feet bgs. The Troll was then lowered into the well to record the water level data. The test ran approximately 18 days (25,902 minutes). The ending water level was measured at 73.47 feet bgs, or within 98 percent of the original (approximately static) water level.

<u>GLA-E Slug Test</u> - The GLA-E slug test was performed on August 2, 2004. Prior to bailing the water level was measured at 99.50 feet bgs. Approximately 155 gallons of water was removed from the well and the water level was measured at 149.86 feet bgs. The Troll was then lowered into the well. The test ran approximately 27 days (39,222 minutes). The ending water level was measured at 77.93 feet bgs, nearly 100 percent of the static water level.

<u>GLA-F Slug Test</u> - The GLA-F slug test was performed on August 2, 2004. Prior to bailing the water level was measured at 69.58 feet bgs. Approximately 280 gallons of water were removed from the well and the water level was measured at 162.30 feet bgs. The Troll was then lowered into the well. The test ran approximately 18 days (25,782 minutes). The ending water level was measured a 69.62 feet bgs, approximately 100 percent of the static water level.

In each case, and as evident from a correlation of the producing fracture identified by an earlier COLOG geophysical survey in well GLA-2, the well data plots as a curvilinear line indicative of a draining condition created by the water cascading down the well from the water producing fracture until the water level had risen to head conditions in that fracture. Once groundwater was recharged to the fracture head elevation, the predicted straight line plot was obtained, characteristic of a recovering well.

3.0 INTERPRETATION OF THE RESULTS

The following sections provide a summary of the results obtained from the borehole excavations, geophysical logging and aquifer tests performed for this supplemental hydrogeologic investigation.

3.1 GEOPHYSICS

3.1.1 Fracture Analysis

An optical televiewer probe was used for fracture and feature analysis since it provides the highest resolution available for fracture and feature analysis in boreholes. The results from the optical televiewer probe were tabulated and graphically presented on rose diagrams and pole plots (Attachment B) to show the distribution of the fractures. On the rose diagrams, the strike azimuth and dip directions are plotted within a 20 degree segments. The following table summarizes the interpretations derived from these plots:

Well	Comments
GLA-A	Based on 28 fractures, the pole-plots show considerable scatter with a predominance of moderate to high-angle fractures. Rose diagrams show dominant northwesterly and northerly strike azimuths of 300-320 degrees and 340-360 degrees and a dominant dip direction to the west.
GLA-B	Based on 21 fractures, the pole-plots show a well defined scatter pattern in the southwest and southeast quadrants with a predominance of moderate to high-angle fractures. Rose diagrams show a dominant strike azimuth of 20-40 degrees and a dominant dip direction to the north-northeast.
GLA-C	Based in 18 fractures, the pole-plots show a well defined scatter pattern in the southeast quadrant with a predominance of moderate to high-angle fractures. Rose diagrams show two dominant northerly strike azimuths of 20-40 and 340-360 degrees with no dominant dip direction.
GLA-D	Based on 36 fractures, the pole-plots show considerable scatter with a predominance of moderate to high-angle fractures. Rose diagrams show a dominant northerly strike azimuth of 340-360 degrees with a dominant dip direction to the west.
GLA-E	Based on 29 fractures, the pole-plots show considerable scatter with a predominance of moderate to high-angle fractures. Rose diagrams show a dominant northerly strike azimuth of 300-320 degrees with a dominant dip direction to the southwest.
GLA-F	Based on 31 fractures, the pole-plots show a well defined scatter pattern concentrating in the southeast quadrant with a predominance of moderate to high-angle fractures. Rose diagrams show two dominant northeasterly to easterly strike azimuths of 20-40 and 60-80 degrees with a dominant dip direction to the northwest.
GLA-G	Based on 29 fractures, the pole-plots show a well defined scatter pattern in the southwest and northeast quadrants with a predominance of high-angle fractures. Rose diagrams show a dominant northerly strike azimuth of 0-20 degrees with a dominant dip direction to the east.
GLA-3S	The number of fractures is small (4 fractures), and the pole-plots and rose diagrams do not contain sufficient data for interpretation.

Well	Comments
GLA-17	Based on 167 fractures, the pole-plots show considerable scatter with a predominance of moderate to high-angle fractures. In addition, rose diagrams show the dominant northerly strike azimuths of 320-340 degrees with the dominant dip direction to the east.
COMPOSITE	Based on all of the fractures measured (363), the pole-plots show a well defined scatter pattern concentrating in the southwest and northeast quadrants with a predominance of moderate to high-angle fractures. In addition, rose diagrams show a dominant northerly strike azimuth of 340-360 degrees and dominant northwesterly and east dip directions.

Based on review of the recent fracture data obtained from eight boreholes with sufficient fractures for trend evaluation, the overall (composite) northerly strike azimuth between 340 and 360 degrees is generally consistent with fracture patterns identified in 12 earlier boreholes. Previous fracture data concluded that although the data may differ from point to point at any given location, there is a predominance of northerly striking fractures paralleling the axis of Gregory Canyon.

3.1.2 Geophysical Analysis

The results from the neutron, gamma, dual-induction, 4pi-density, and water quality logs were used to evaluate the character of fractures identified in the fracture analysis and possible water producing zones. Neutron logs were used to identify relative changes in hydrogen which can be correlated to water; gamma logs were used to identify weathered (clayey) intervals; dual-induction and 4pi-density logs were used to identify fractured (less dense) intervals; and the water quality logs were used to measure relative changes in temperature and electrical conductivity. The logging was helpful in describing the drilled rock section, but was not generally successful in defining specific water producing fractures or zones. However, based on the sum of geophysical analysis to date, it is apparent that groundwater flow in Gregory Canyon point of compliance wells occurs within transmissive fractures, and can be separated into two distinct zones. Groundwater in the "canyon" area (e.g., wells GLA-B, -C, and -G), occurs within the weathered bedrock, while groundwater in the western "saddle" area (e.g., wells GLA-A, GLA-D, GLA-E, and GLA-F) occurs within the unweathered bedrock and the transmissive fractures are few. This is consistent with earlier GLA observations (GLA, 1997) that identified average yield and low-yield wells. The average yield wells (wells yielding from 5 to 20 gpm) were found to be located within Gregory Canyon itself, while the low-yield wells (e.g., wells GLA-1, GLA-2, GLA-4 and dry well GLA-9) with recovery rates less than 5 gpm, are located along the western ridgeline.

3.2 AQUIFER TESTING

Long-term aquifer test data were analyzed using AquiferTest Pro, Version 3.5, numerical modeling software (Röhrich and Waterloo Hydrogeologic, 2002) to calculate aquifer hydraulic properties. A summary of the calculated hydraulic properties from the aquifer tests, including aquifer tests performed in 2000 (GLA, 2001), are presented in Table 3 and the individual calculations and plots are included in Attachment C.

3.2.1 Aquifer Classification

Using the information contained on the boring logs, geophysical logs, and well construction summary diagrams (Attachments A and B), the aquifer interval, aquifer type, and degree of well screen penetration were determined for each tested well. The results of the classification are summarized below.

Well	Depth to Water (fbgs)	Screen Interval (fbgs)	Aquifer Interval (fbgs)	Aquifer Flow Condition	Aquifer Screen Penetration
GLA-A	73.30	74.4-104.4	85-103	Fracture Flow	Partial
GLA-B	40.00	51.2-91.2	40-84	Fracture Flow	Partial
GLA-C	37.12	41.0-81.0	40-80	Fracture Flow	Partial
GLA-D	60.27	95.1-145.1	93-137	Fracture Flow	Partial
GLA-E	77.6	Open Hole	83-133	Fracture Flow	Partial
GLA-F	69.6	Open Hole	69-152	Fracture Flow	Partial
GLA-G	40.18	61.5-101.5	43-101	Fracture Flow	Partial
GLA-2	73.28	70.38-95.38	83-85	Fracture Flow	Partial
GLA-3	25.0	Open Hole	NA	Fracture Flow	Partial
GLA-12	37.92	32.0-52.0	NA	Fracture Flow	Partial
GLA-13	50.50	49.5-69.5	NA	Fracture Flow	Partial
GLA-14	37	35.5-55.5	NA	Fracture Flow	Partial

Note: NA – Not Available/Optical televiewer evaluation was not performed.

3.2.2 Calculated Long-Term Specific Capacity

The long-term specific capacity value was calculated for each of the tested wells and the resulting values are summarized on Table 3. The calculated values for the monitoring wells ranged from 0.06 to 1.11 gallons per minute per foot of drawdown (gpm/ft), with the range of specific capacities being generally higher for wells located in the "canyon" area.

3.2.3 Calculated Hydraulic Properties

The long-term constant rate aquifer test data were evaluated using Cooper-Jacob straight-line solution (1946), Theis-curve fitting solution (1935), and, Moench Fracture Flow solution (1993). Hydraulic conductivity calculations were also completed for slug tests using Bower and Rice solution (1976) using aquifer recovery data. Plots showing the best fit for the data are presented in Attachment C. The analyses were biased toward the "middle- to late-time" portions of the data plots so as not to include data obtained during well casing and filter pack dewatering.

The calculated hydraulic conductivity (K), transmissivity (T), and storativity (S) values that were obtained from the aquifer pumping test data are summarized in Table 3 along with aquifer pumping test data obtained from wells GLA-3 and GLA-8 during the Phase 5 Supplemental Investigation (GLA, 2001). As shown on Table 3, for the recent pumping tests, the range of calculated K values ranged from 1.75E-05 to 24.6 feet/day, with K values highest in the "canyon" area (0.137 to 24.6 feet/day for the canyon wells). Bedrock transmissivity values were derived from the computed hydraulic conductivity values in the canyon wells, and aquifer thickness estimates, based in part on well tests by

COLOG summarized in Section 3.1. As shown on Table 3, transmissivity values ranged from 8.77 to 650 ft^2/day. Bedrock storativity values ranged from 1.99 E-06 to 0.28.

Hydraulic properties calculated from the earlier (GLA, 2001) aquifer pumping tests at wells GLA-3 and GLA-8 are generally consistent with the more recent test data. Hydraulic conductivities calculated range from 8.96E-02 to 19.15 feet/day, a slightly broader range of values that are skewed lower by the K value calculated in upper canyon well GLA-8, but consistent with wells within the canyon area of the site as compared to the saddle wells. Bedrock transmissivity values range from 1.25 to 352 ft^2/day, and bedrock storativity values range from 8.87E-08 to 0.41, which are within the range of values for these parameters and include slightly lower values than the recently tested canyon wells.

4.0 DISCUSSION

Successive investigations of Gregory Canyon begun in 1991 have added incrementally to the body of data and observations underlying a basic understanding of the site hydrogeology. The recent work described above, which is the basis of this supplemental report, similarly enables updates and revisions to that understanding. The additional observations addressed here relate to the nature of recharge derived from Gregory Mountain, the mineralization of fractures, the effect of the weathering zone on fracture flow, and the apparent flow barrier formed by the western ridgeline of Gregory Canyon.

<u>Recharge</u>. The influence of Gregory Mountain in terms of groundwater recharge to its adjacent areas is clear from inspection of Figure 1; no other topographic element in the area is as likely a source of recharge to Gregory Canyon. The western ridgeline of Gregory Canyon is a relatively minor topographic feature, which would contribute little to the canyon recharge even assuming hydraulic properties similar to those of Gregory Mountain. It is likely that the recharge mound below Gregory Mountain is symmetrical and elongated in a north-south orientation, reflecting the mountain's flat-topped morphology, trend and size. In addition, it is evident from air photo analysis that the leucogranodiorite underlying the mountain is cut by pronounced intersecting fractures capable of conveying precipitation below ground.

Recharge from Gregory Canyon flows via fractures below an equipotential surface to the alluvial aquifer of the San Luis Rey River. The water level in the alluvium adjacent the bedrock, which fluctuates seasonally and with climatic intervals, is the local base level of the equipotential surface. The quantity of water transmitted to the alluvial aquifer through the fractures is minor relative to the volume of water transmitted through the alluvium even in dry periods. During wet periods, whether considered on an annual or decadal basis, water levels rise in the alluvial aquifer at the mouths of adjoining canyons, and the adjacent equipotential surface expands as the bedrock's fracture system fills. At the present time of extended drought, the water level in the alluvial aquifer has dropped below the screen levels of wells at the mouth of Gregory Canyon, and the bedrock equipotential surface has similarly contracted.

Fracture Mineralization. The majority of fractures observed in downhole videos or other images are filled by mineralization. Some of these features are pegmatite dikes or veins related to intrusion of the leucogranodiorite into the tonalite host rock. However, most are younger mineral veins filling fractures of tectonic origin that cross-cut the pegmatite dikes and veins. The mineral assemblage filling the younger fractures consists of epidote, chlorite, and a probable zeolite mineral (presumably laumontite). Both fractures and mineralization are presumably related chiefly to stresses and hydrothermal activity along the Elsinore fault, located about 5½ miles to the northeast; these mineral veins. Low temperature hydrothermal zeolite assemblages are found in basement rocks along strike-slip faults elsewhere in Southern California. In face, the name *Aqua Tibia* given to the segment of the San Luis Rey River basin where it crosses the Elsinore fault is consistent with this observation.

Weathering. Another feature of the site not previously emphasized is the weathering profile shown in the sections of Plates 2 and 3. As interpreted from drilling logs, the zone of weathering is deeper along the invert of Gregory Canyon and shallows on the sidewalls. It should be noted that weathering is different in kind from, and younger than hydrothermal mineralization. Flow apparently is enhanced even by a moderate degree of rock decomposition and mineral vein dissolution. Relatively significant water producing zones are mostly located in the weathered zone in wells near the canyon axis. In contrast, flow in unweathered rock is more limited in terms of both quantity and occurrence of producing fractures.

Flow Barrier. The sum of observations to date suggests that fracture flow below the weathered zone is limited. Four wells drilled along the west ridgeline to depths significantly below the projected equipotential surface are dry (one well, GLA 4 is recharged by a perched water condition), and other wells drilled in unweathered bedrock underlying the northern extension of the west ridgeline (in the low flow zone shown on Plates 1 and 2) recharge very slowly from relatively isolated fractures. Therefore, the west ridgeline is believed to form a groundwater flow barrier. This interpretation is included on Plate 1, which illustrates modified equipotential and water table contours based on this interpretation. Plate 1 indicates that fracture flow below the equipotential surface is west northwest from the Gregory Mountain recharge area to Gregory Canyon; occurs largely in the weathered zone; and is bounded by unweathered tonalite under the west ridgeline.

This finding supports the interpretation presented in GLA's Phase 5 Hydrogeologic Investigation Report (GLA, 1997), which stated that:

> "...cores of only slightly weathered tonalite form boulder knobs throughout the western flank of Gregory Canyon. This surface observation holds true for all the wells drilled along the western ridge (GLA-1, GLA-2,GLA-4, and GLA-9), which after going through a thin interval of weathered rock encountered hard, unaltered, and very sparsely fractured tonalite. It appears, thus, that the geomorphic expression of the western ridge results from an underlying core of comparatively pristine tonalite. ...The low-yield of these wells, coupled with the observation made before regarding the hard and sparsely fractured nature of the substrate,

> suggests that the western and southern ridges act as low permeability barriers along the periphery of the site."

Hydraulic Communication. Despite relatively high fracture frequencies observed in wells and in limited outcrops there are few water-producing fractures in the Gregory Canyon boreholes and wells. Mineralization of the fracture system appears to explain the paucity of water-producing fractures. Hydraulic communication between these boreholes might be better visualized as occurring in a system of interconnected channel-ways within the mineralized vein system of the weathered zone, rather than as a system of intersecting open fractures.

Fracture flow models typically do not specifically account for mineralized fracture systems, unless the effect is accounted for by default assumptions about fracture apertures. In a discussion of fracture frequency, fracture spatial density, and connectivity of fracture networks, Renshaw (2000) suggests that for the typical range of fracture spatial densities, connectivity of fractures is on the order of 30% or less. Renshaw (2000) further notes that,

> "...once a network is connected, the primary source of uncertainty in predicting the permeability of fractured rock does not arise from uncertainty in the connectedness of the network, but rather from uncertainty in the transmissivities of the individual fractures, which arises from uncertainty in the fracture apertures, state of stress, and multiphase flow effects".

This statement suggests that there are two determinations to be made in characterizing a fracture flow network. The first is to determine if the fracture network is connected, the second is to determine the transmissive nature of the whole fracture system.

With respect to the first determination, well tests as reported herein provide direct evidence of connectivity. While it is problematic to specify the fraction of interconnections within the fracture system, especially given the complicating factors of mineralization and weathering, it is possible based on well response to drawdown to assess the relative connectivity of adjacent bedrock domains.

With respect to the second determination, system transmissivity cannot be determined from well tests on individual fractures. Thus, hydraulic calculations as presented herein serve to provide a sense of the range of parametric values related to isolated segments of individual fractures, but do not provide an estimate of the average parametric values of all fractures in the system.

Monitoring Wells. The line of wells across the mouth of Gregory Canyon inclusive of GLA-14 and GLA-12 spans two bedrock domains apparently reflecting two degrees of fracture interconnectivity. Relative to Plate 1, and as presented in the table below, those wells east of and including GLA-13 all show a response to drawdown of other wells in that group.

Well	Adjacent Well	Distance (ft.)	Communication Test Reference
GLA-12	GLA-G	101.5	GLA-G pumping test (2004)
GLA-G	GLA-B	101	GLA-G pumping test (2004)
GLA-B	GLA-C	135	GLA-B pumping test (2004)
GLA-C	GLA-3	240	GLA-3 pumping test and GLA-B pumping test (2004)[1]
GMW-1	GLA-13	200	GLA-3 pumping test (2001)
GLA-3	GMW-1	51	GLA-3 pumping test (2001)
GLA-13	GLA-D	172	GLA-13 pumping test (2004)
GLA-D	GLA-F	90	GLA-A pumping test (2004)[2]
GLA-F	GLA-2	50	GLA-A pumping test (2004)[2]
GLA-2	GLA-E	110	GLA-A pumping test (2004)[2]
GLA-E	GLA-A	80	GLA-A pumping test (2004)[2]

1- GLA-3 pumping test demonstrates response between GLA-3 and GLA-B at a distance of 370 feet, and the GLA-B pumping test demonstrates response between GLA-B and GLA-C.

2- Communication is inferred from a response in observation well GLA-D during the GLA-A pumping test, and wells GLA-E and GLA-F were completed to provide additional monitoring capabilities within the low-flow zone.

In contrast, wells west of GLA-13 (in the low flow zone) have not been shown to respond similarly. This does not suggest that the wells in the low flow zone are isolated from each other or from wells east of and including GLA-13, since the projected equipotential surface includes all of the well data. Rather it suggests that the fraction of connected fractures within the low flow zone is less than in the bedrock domain to the east, assuming no difference in the transmissivity of the fractures. While a smaller well spacing in the low flow zone could be utilized to identify a similar drawdown response, it is not necessary to place additional wells in the low flow zone to detect contaminant transport because all fractures are recharged from the same source.

The currently proposed monitoring wells are located ideally for downgradient monitoring. As a result, the groundwater flow direction is effectively parallel to this groundwater flow barrier so that groundwater flowing under the landfill footprint will be brought to the line of compliance wells. Bedrock well GLA-14 is well situated for monitoring the efficacy of the groundwater barrier. Similarly, since the two dimensional flow model performed by GLA (1995) showed that groundwater would migrate along the southern limit of the alluvial groundwater section, alluvial wells GLA-16 and SLRMWD#34R are well situated for monitoring downgradient of the point of compliance monitoring system. A more detailed discussion of the proposed groundwater monitoring system is provided below.

Groundwater Monitoring System. The following sections describe the groundwater monitoring system proposed to evaluate groundwater conditions at the GCLF in accordance with CCR Title 27 §20405, and 40 CFR 258.51 through 258.54. The monitoring system's first defense beyond the landfill liner system is the series of weathered/fractured bedrock wells proposed along the downgradient limit of the landfill or POC. All of the bedrock wells are screened across the first water bearing zone with the majority of these wells screened across the upper more weathered/fractured bedrock zone and thus the more highly conductive portion of the fractured bedrock flow system. However, a dual detection monitoring system, which includes dedicated wells in both the alluvial and fractured bedrock groundwater systems, is proposed.

The detection monitoring program will include downgradient wells to collect representative samples of groundwater at the POC, and upgradient wells to collect samples of groundwater that are representative of background conditions. As currently proposed, with the exception of the spacing between wells GLA-14 (west of the landfill) and GLA-A, the wells are spaced about 50 to 240 feet apart, with a higher density of wells (closer spacing) along the western ridge saddle area of the site (wells GLA-A, GLA-D, GLA-E, GLA-F, and GLA-2) where there are fewer interconnected water bearing fractures. Wells GLA-14 and GLA-A, which are currently constrained by the SDCWA aqueduct easement are spaced approximately 400 feet apart. As presented herein, cross-hole testing performed following well construction demonstrates that the proposed monitoring network will be able to provide the earliest detection of a release of waste constituents to ground water from the proposed solid waste management unit at Gregory Canyon. As an additional groundwater system enhancement, each of the bedrock POC wells will be equipped with a dedicated pump and plumbed to convey groundwater to an on-site tank. In this way, a hydraulic barrier will be maintained along the POC and capture the groundwater as it flows to the POC. The detection monitoring program system is summarized in the following table.

Gregory Canyon Landfill
Detection Monitoring Program

Monitoring Point	Unit	Monitoring Point I.D.	Status
Groundwater Monitoring Well	Bedrock	GLA-4, GLA-5, GLA-11, GLA-18*	Background/ Cross-gradient
Groundwater Monitoring Well	Bedrock	GLA-2, GMW-1, GLA-12, GLA-13, GLA-14, GLA-A, GLA-B, GLA-C, GLA-D, GLA-E, GLA-F, and GLA-G	Compliance
Water Level Measuring Station	Bedrock	GLA-1, GLA-3, GLA-7, GLA-8, GLA-10	Not Applicable
Groundwater Monitoring Well	Alluvial	Lucio #2R	Background
Groundwater Monitoring Well	Alluvial	GMW-3	Compliance
Groundwater Monitoring Well	Alluvial	GLA-16, SLRMWD #34R	Sentry
Surface Water Station	Gregory Canyon	GCSW-2	Compliance
Surface Water Station	San Luis Rey River	SLRSW-1	Background
Surface Water Station	San Luis Rey River	SLRSW-2	Compliance

*Proposed well to be constructed.

Groundwater Monitoring Points – For the bedrock fracture flow system, POC groundwater monitoring wells include GLA-12, GLA-13, GLA-14, GLA-2, GMW-1, and GLA-A through GLA-G, as shown on Figure 2. Wells GLA-1, GLA-3, and GLA-10, will be utilized as water level measuring station and as contingency monitoring wells. In addition, though wells GLA-7 and GLA-8 are located within the future landfill footprint, they will also continue to be used as water level measuring stations until landfill development reaches their location, at which time they will be properly abandoned.

Existing wells GLA-4, GLA-5, GLA-11, and proposed well GLA-18 (located on the east side of the landfill footprint) will be background wells. Of these wells, the only well that cannot be constructed prior to landfill operations is GLA-18. Because of the steep slopes, access to this well location is not anticipated until the landfill operations extend a significant distance up the canyon and the utility pad is constructed. Until that time, a drill rig will not be able to gain access to the area for well construction.

The water quality monitoring program will also include monitoring of the San Luis Rey River valley alluvial prism from compliance well GMW-3, Lucio Dairy well #2R (located at the Lucio Dairy near the northeastern property boundary). Wells GLA-16 and SLRMWD#34R will serve as alluvial "sentry" wells located further downgradient of the facility along the modeled groundwater flowpath (GLA, 1995). Under this monitoring program, the proposed monitoring well network will be maintained throughout the life of the landfill and through the post-closure period. Existing wells, which are not included within the monitoring network but are located within the footprint of the landfill will be properly abandoned prior to landfilling in that area. It should be noted that in the event that facility construction requires the destruction of any of these wells (e.g., a well located in the proposed ancillary facilities area), a replacement well would be constructed in the vicinity of the originally designated well.

Groundwater Sampling Procedures. The following sampling procedures provide minimum requirements that shall be followed when performing groundwater sampling at the Gregory Canyon Landfill. Depending on the location of the well two separate sampling procedures are proposed for the GCLF. As a result of the hydraulic barrier at the POC, all compliance bedrock aquifer wells will be sampled in accordance with the procedures discussed under the bedrock compliance well sampling procedures section. All other wells (alluvial and bedrock-background/cross-gradient) will be sampled in accordance with the procedures discussed under standard sampling procedures section.

Procedures to be used for groundwater sampling are outlined in the *Practical Guide for Groundwater Sampling* and *RCRA Groundwater Monitoring Technical Enforcement Guidance Document*.

Standard Purging Procedures for Sampling – Prior to collecting groundwater samples, purging of a well is necessary to provide a representative sample of groundwater that approximates formational conditions. Temperature, pH, turbidity, and EC or conductivity of the purged water are measured to evaluate whether stable conditions have been achieved. It is assumed that stability or formational conditions have been achieved when the difference between successive field indicator measurements is less than ten percent. The amount of water that must be purged from a well is a function of the stability of the measured parameters, as well as the recovery rate of the well. Purging should be performed at a sufficiently slow rate so that recharging water does not cascade in the filter pack and casing.

A well is considered to be fast recharging if groundwater levels recover to within 80 percent or more of the original static water level within two hours of purging. A minimum of one borehole volume should be purged before temperature, pH, turbidity, and EC parameters are measured in the purged water. An additional one-half borehole volume should be purged prior to re-measuring the water quality parameters. It is assumed that stability or formational conditions have been achieved when the difference between successive measurements is less than ten percent. If the values vary by more than 10 percent, additional one-half borehole volumes should be purged until temperature, pH, and EC parameters have adequately stabilize, up to a total of three borehole volumes. The well should be allowed to recharge to 80 percent of its static condition prior to sample collection.

A well is considered to be slow recharging if groundwater levels do not recover to within 80 percent or more within two hours of purging. Slow recharging wells should be purged by removing one borehole volume of water, and then allowing the well to recover for up to two hours prior to collecting samples.

A borehole volume is the amount of water contained within the casing of a well (called a casing volume) plus the water contained within the filter pack surrounding the well casing. The following equation is used to calculate the borehole volume in the screened interval of a well:

$$\text{Borehole volume (gallons)} = (7.48\pi/4)[CD^2+P(BD^2-CD^2)](WD-GW)$$

Where:

BD = borehole diameter (feet)
CD = casing diameter (feet)
P = porosity of filter pack (as a decimal)
WD = well depth (feet)
GW = depth to groundwater (feet)

The following equation is used to calculate the borehole volume in the unscreened interval of a well:

$$\text{Borehole volume (gallons)} = (7.48\pi/4)(CD^2)(WD-GW)$$

Where:

CD = casing diameter (feet)
WD = well depth (feet)
GW = depth to groundwater (feet)

Bedrock Compliance Well Purging Procedures for Sampling – As a result of very low flow rates in the majority of bedrock wells at the POC, a permanent dewatering condition at the POC is proposed of for the GCLF, thereby creating a hydraulic sump. To achieve a permanent dewatering condition at the POC, bedrock wells will be equipped with float sensors and electric submersible pumps. As a result, additional purging of bedrock wells at the POC is unnecessary to provide a representative sample of groundwater that approximates formational conditions. Prior to sample collection each bedrock well would be allowed to recover (no greater than 48 hours), until a sufficient volume of water enters the well to collect a sample.

5.0 CONCLUSIONS

In summary, the following conclusions can be made from the hydrogeologic conditions observed during this investigation:

- Based on exploratory boring GLA-17 and previous drilling (GLA-4, GLA-9 and GMP-3), the western tonalite ridge acts as a groundwater barrier forcing groundwater to move parallel to this boundary and down the axis of Gregory Canyon;
- Fracture analysis indicates a strong north-trending fracture orientation parallel to the axis of Gregory Canyon;
- Interpretation of boring logs indicates a thicker sequence of weathered bedrock near the axis of Gregory Canyon;
- Pumping test results indicate that the "canyon" wells provide significantly greater flow rates compared to the western "saddle" wells;
- Pumping tests conducted between the "canyon" wells (i.e., wells east of and including GLA-13) indicate hydraulic interconnections as exhibited by the response to drawdown between these wells; and
- Slug tests in the western "saddle" area indicate fewer interconnected fractures as a result of significant mineralization within fractures and a lack of weathering within the bedrock.

Based on these observations, groundwater is interpreted to flow north-northwest down the axis of Gregory Canyon towards the San Luis Rey River. As in previous hydrogeologic studies for the Gregory Canyon site, the hydrogeologic data support the interconnectivity of the fracture flow system across the site, albeit at a lesser degree of connectivity within the low flow zone. Since the bedrock fracture flow system is recharged from the same source, all of the proposed groundwater monitoring wells sample the same groundwater, and as a result the groundwater monitoring network will provide chemical evidence of contaminant transport along the point of compliance. Given this interpretation, the proposed groundwater monitoring network for the Gregory Canyon Landfill is adequate to monitor potential release from the site. It should be noted, that the Gregory Canyon Landfill incorporates additional monitoring capacity through the installation of a leak detection layer between the upper and lower HDPE liner systems, which will provide the earliest detection of a release from the landfill.

6.0 CLOSURE

This report is based on the data presented above and described herein. GeoLogic Associates should be notified of any conditions that differ from those described herein since this may require reevaluation of the data, conclusions, and work plan detailed above. This report has not been prepared for use by other parties or projects other than those described above. It may not contain sufficient information for other parties or purposes.

This report has been prepared in accordance with generally accepted geotechnical and hydrogeologic practices, and makes no warranties, either expressed or implied, as to the professional content and data presented herein.

GeoLogic Associates

William B. Lopez, CHg, CEG
Project Geologist

Gary L. Lass, CHg, CEG
Principal-in-Charge

7.0 REFERENCES

Bouwer, H., and R.C. Rice, 1976, "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells," Water Resources Research, Vol. 12, No. 3.

California Department of Water Resources, 1990, "California Well Standards," Bulletin No. 74-90.

Cooper, H.H., and C.E. Jacob, 1946, "A generalized graphical method for evaluating formation constants and summarizing well field history," Transactions of the American Geophysical Union, Vol. 27, No. 4.

GeoLogic Associates, 1995, "Two-Dimensional Flow Model, Proposed Landfill at Gregory Canyon," prepared for Gregory Canyon Ltd., October.

GeoLogic Associates, 1997, "Phase 5 Hydrogeologic Investigation, Proposed Gregory Canyon Landfill, San Diego County, California," prepared for Gregory Canyon Ltd., January.

GeoLogic Associates, 2001, "Phase 5 Supplemental Investigation, Results of Pumping Tests," prepared for Gregory Canyon Ltd., January.

GeoLogic Associates, 2003, "Geologic, Hydrogeologic and Geotechnical Investigations Report, Gregory Canyon Landfill," prepared for Gregory Canyon Ltd., May 2003, revised November 2003.

Moench, A.F., 1993, "Computation of Type Curves for Flow to Partially Penetrating Wells in Water-Table Aquifers" in Groundwater, Vol. 31. no. 6. pp. 966-971.

Renshaw, 2000, "Fracture Spatial Density and the Anisotropic Connectivity of Fracture Networks," in Faybishendo, B., Witherspoon, P.A., and Benson, S.M., eds., Dynamics of Fluid in Fractured Rock, AGU Monograph 122.

Röhrich, Thomas, and Waterloo Hydrogeologic, Incorporated, 2002, "AquiferTest Pro, Advanced Pumping Test and Slug Test Analysis Software, Version 3.5.

Theis, C.V., 1935, "The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage," Transactions of the American Geophysical Union, Vol. 16.